Towards microwave and THz spectroscopy using Rydberg He

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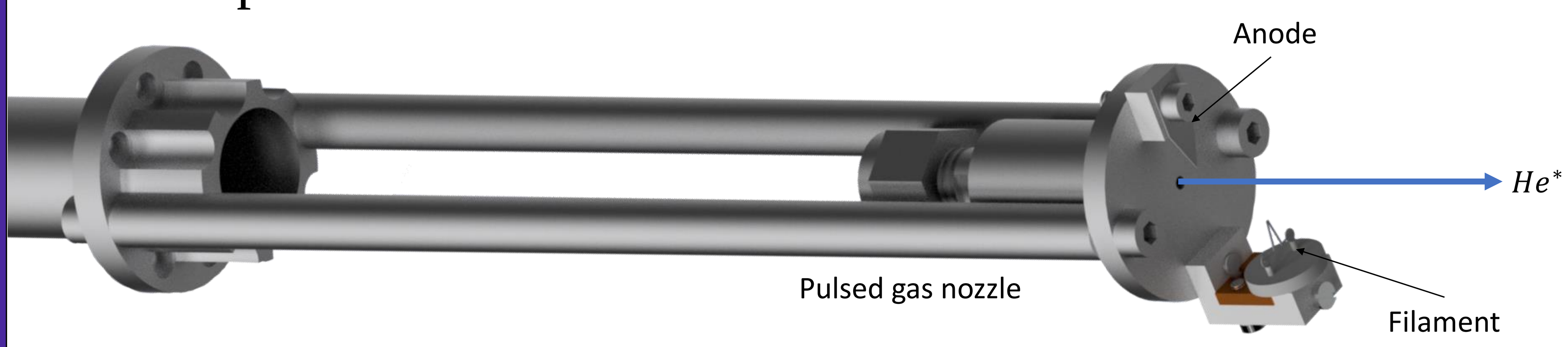
Introduction

Recent experiments involving the microwave spectroscopy of positronium (Ps) yielded asymmetric lineshapes for the fine structure of Ps [1]. In an effort to eliminate experimental systematic errors, the experiments are to be repeated with Rydberg atomic helium (He). A pulsed supersonic jet of He atoms in the metastable $1s2s\,^3S_1$ state generated in a DC electric discharge [2] is excited to $1snp\,^3P_J$ Rydberg states via single-colour single-photon laser excitation. Rydberg spectra have been recorded and the $n = 31$ and $n = 36$ states have been characterised by state-selective field ionisation. Microwave and THz spectroscopy will be performed on these states and later, the systematic errors in microwave guide experiments will be probed.



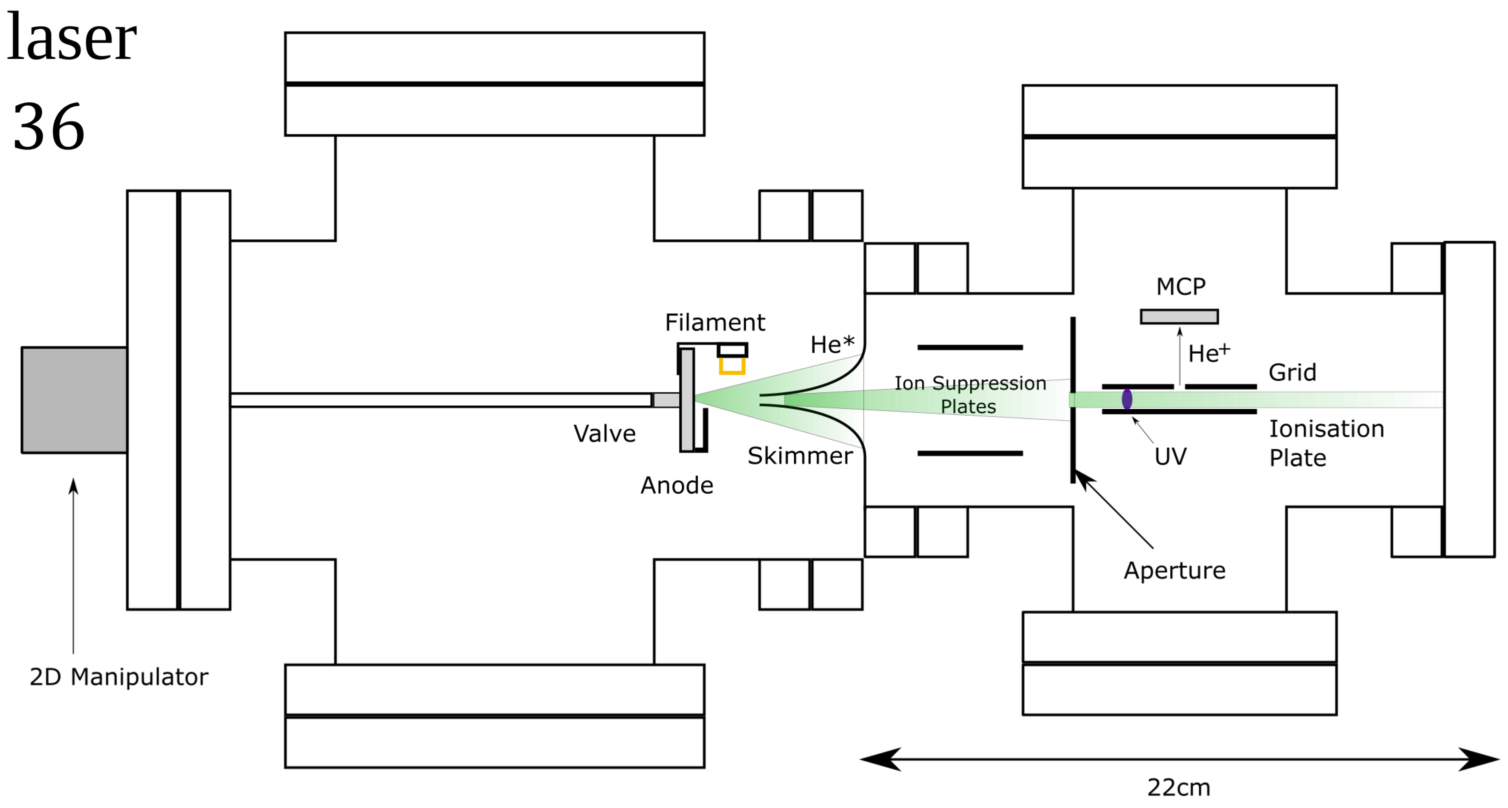


Fig. 1: Schematic of current experimental apparatus.

Characterisation of Rydberg States

- Rydberg states of He in the range $27 \leq n \leq 57$ have been resolved.
- State-selective electric field ionization of Rydberg states have been performed.

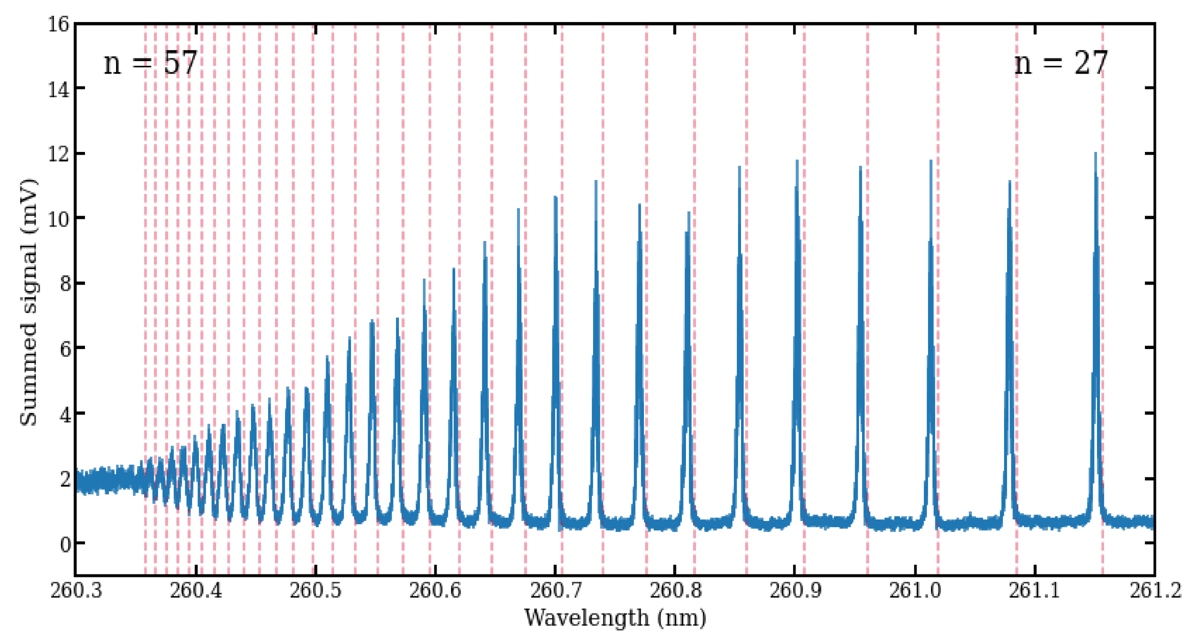


Fig. 3: Measured Rydberg Spectra.

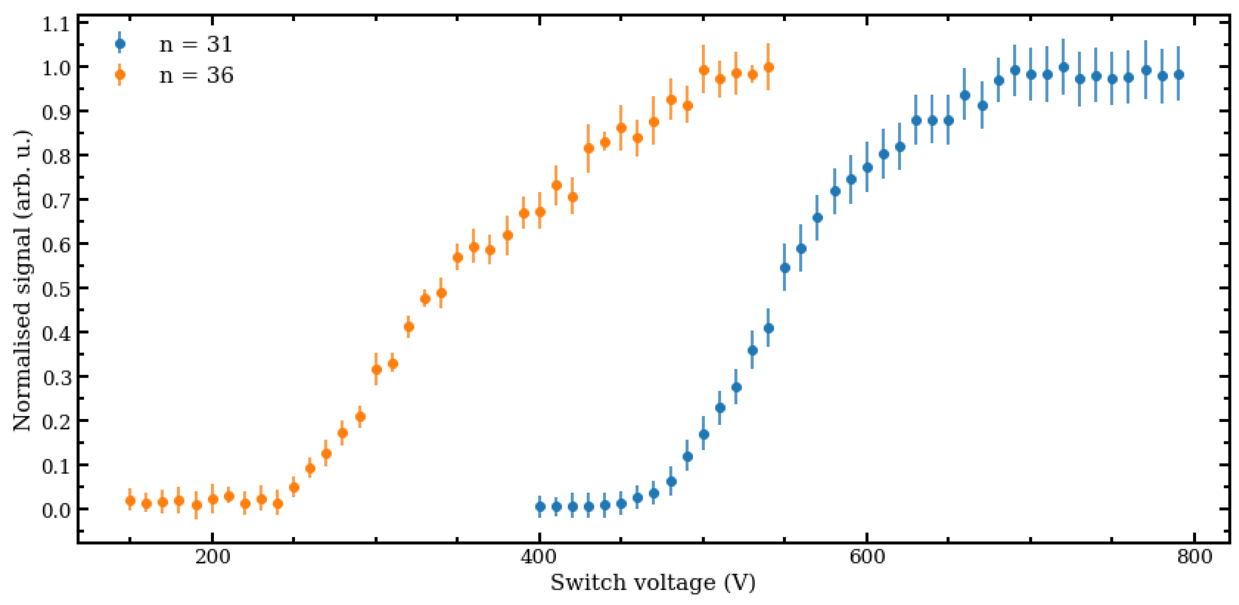


Fig. 4: State-selective field ionization for n=31 and n=36.

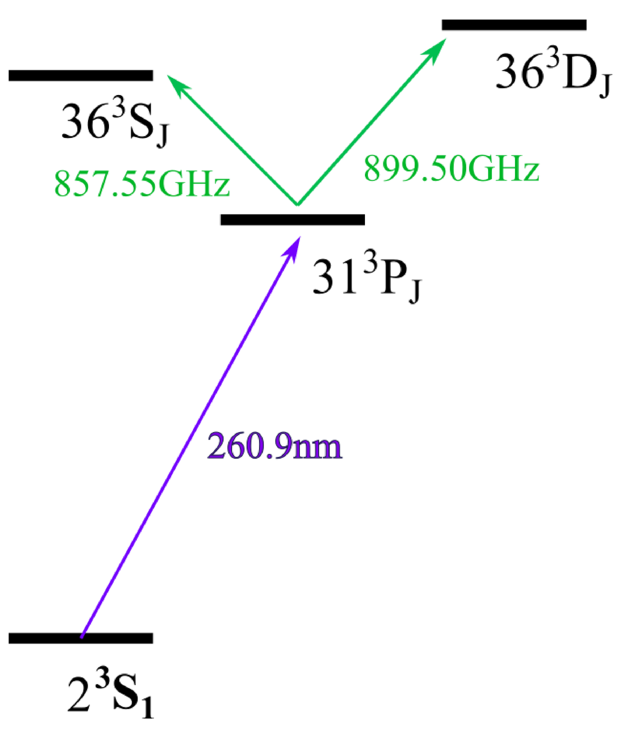


Fig. 2: Energy-level diagram showing possible single-colour single-photon excitation pathways.

Calculations

- THz transition energies for 2 waveguides have been calculated [3].
- Microwave transition energies for the waveguides used for Ps spectroscopy measurements show that characterisation measurements can be performed with He.
- Fluorescence lifetime calculations of high n Rydberg states permit SOF experiments [4].

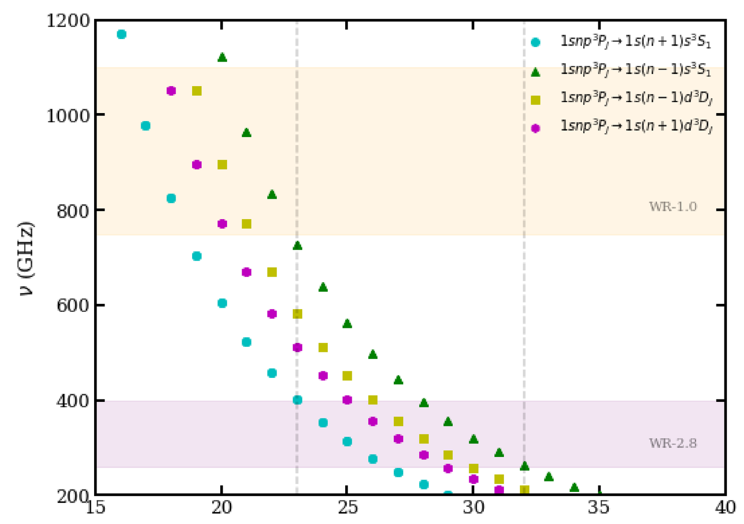


Fig. 5: Targetable single-photon THz transitions

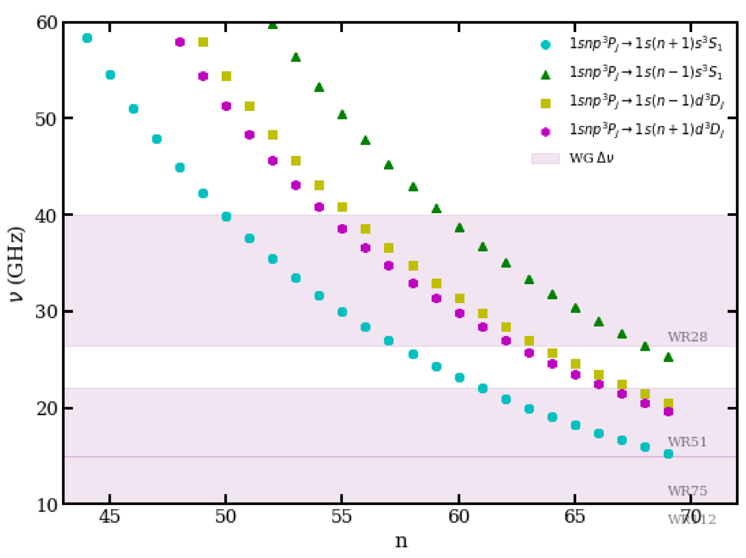


Fig. 6: Targetable single-photon microwave transitions.

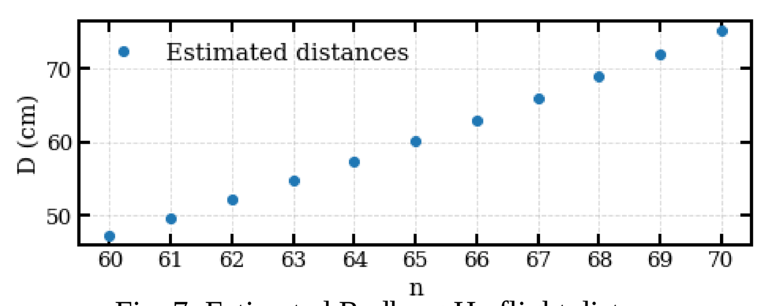


Fig. 7: Estimated Rydberg He flight distances.

Outlook

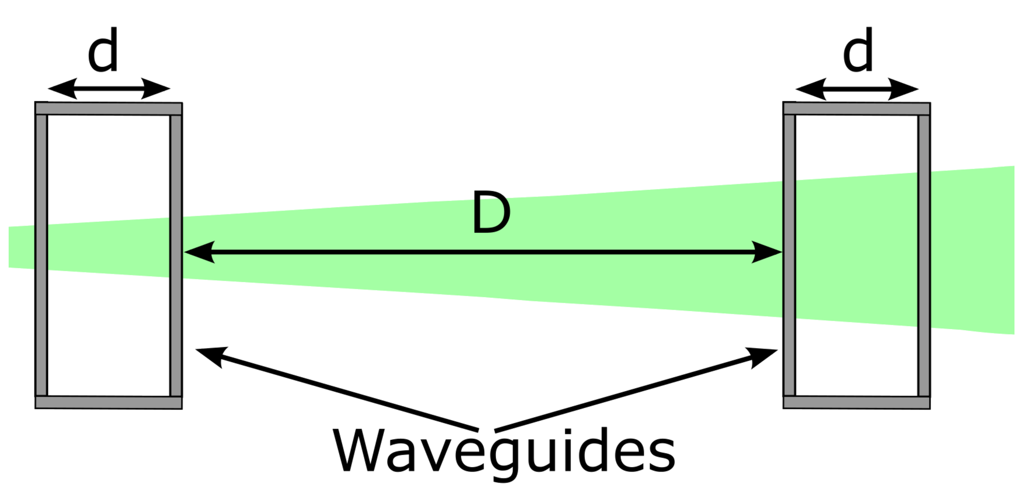


Fig. 8: Example configuration for spatially separated oscillatory field measurements where the green cone indicates a beam of atoms, and the grey boxes are identical microwave guides.

- Characterisation of microwave guides to identify systematic errors in measurements of the Ps $n = 2$ fine-structure and as a pre-cursor to spatially separated oscillatory field (SOF) measurements [5].
- Frequency offset SOF measurements to eliminate the need for lineshape modelling in fine structure measurements [6].
- THz lineshape measurements in preparation for temporal SOF experiments. Followed by Precision measurement of the Ps Rydberg constant using THz sources.

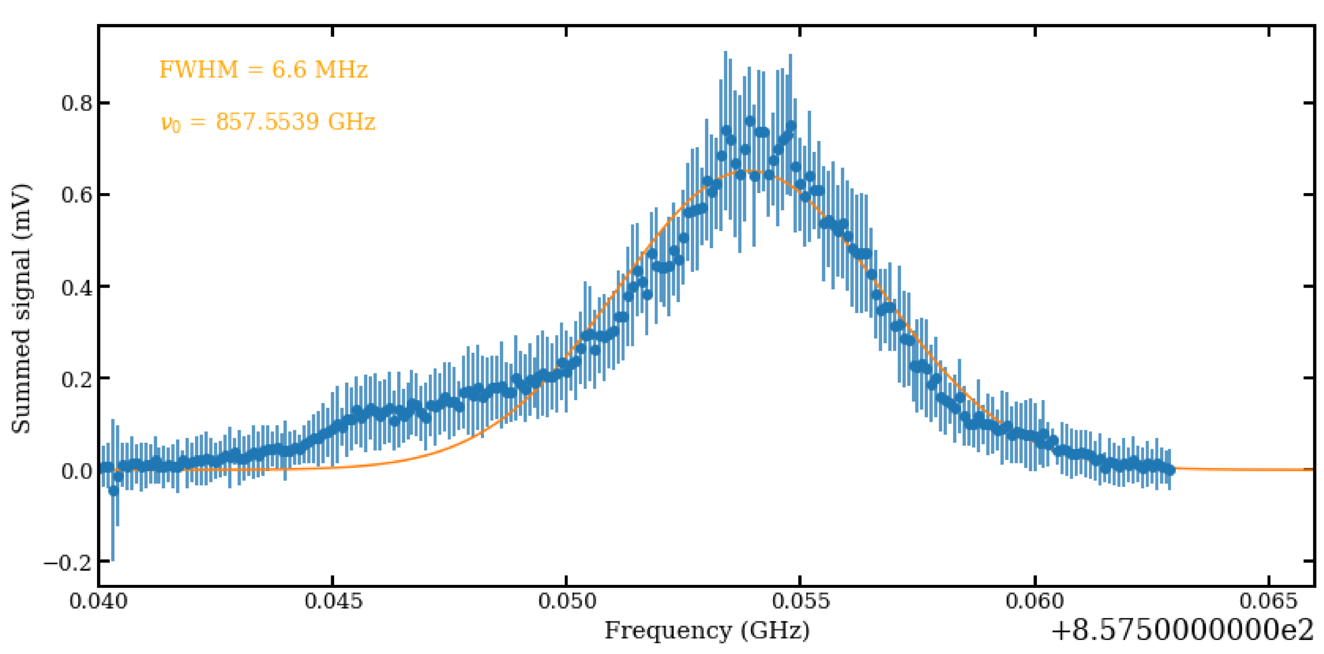


Fig. 9: Measured THz linewidth for n=31 to n=36 transition.

References

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